

Claims

- [c1] A method of forming a tantalum–nitride diffusion barrier region on a low–k material substrate, the method comprising the steps of:
- forming a protective layer on the low–k material substrate by plasma–enhanced atomic layer deposition (PE–ALD) from a tantalum–based precursor and a nitrogen plasma; and
- forming a subsequent substantially stoichiometric tantalum–nitride diffusion barrier layer by PE–ALD from the tantalum–based precursor and a plasma of hydrogen and nitrogen.
- [c2] The method of claim 1, wherein the tantalum–based precursor is selected from the group consisting of: tantalum pentachloride (TaCl_5), tantalum pentaiodide (TaI_5), tantalum pentafluoride (TaF_5), and tantalum pentabromide (TaBr_5).
- [c3] The method of claim 1, wherein each forming step further includes:
- exposing the substrate to the tantalum–based precursor prior to the PE–ALD in a chamber; and
- evacuating the chamber after the PE–ALD.

- [c4] The method of claim 1, wherein the protective layer forming step further includes providing a carrier gas for the tantalum-based precursor.
- [c5] The method of claim 1, wherein the protective layer includes a higher content of nitrogen than tantalum.
- [c6] The method of claim 1, wherein the protective layer forming step includes exposing the low-k material substrate for greater than 1000 Langmuirs.
- [c7] The method of claim 1, wherein the low-k material substrate is selected from the group consisting of: silicon dioxide (SiO_2) and hydro-fluoric (HF) dipped silicon (Si).
- [c8] The method of claim 1, wherein the tantalum-nitride diffusion barrier layer is thicker than the protective layer.
- [c9] A method of forming a tantalum-nitride diffusion barrier region on a low-k material substrate, the method comprising the steps of:
 - forming a protective layer on the low-k material substrate by conducting a first number of first cycles in a chamber, each first cycle including:
 - exposing the substrate to a tantalum-based precursor,
 - evacuating the chamber,
 - plasma-enhanced atomic layer depositing (PE-ALD) from

the tantalum-based precursor and a nitrogen plasma,
and
evacuating the chamber; and
forming a subsequent substantially stoichiometric tantalum-nitride diffusion barrier layer by conducting a second number of second cycles in the chamber, each second cycle including:
exposing the substrate to a tantalum-based precursor,
evacuating the chamber,
PE-ALD from the tantalum-based precursor and a plasma of hydrogen and nitrogen, and
evacuating the chamber.

- [c10] The method of claim 9, wherein the tantalum-based precursor is selected from the group consisting of: tantalum penta-chloride (TaCl_5), tantalum penta-iodide (TaI_5), tantalum penta-fluoride (TaF_5), and tantalum pentabromide (TaBr_5).
- [c11] The method of claim 9, wherein the exposing steps further include providing a carrier gas for the tantalum-based precursor.
- [c12] The method of claim 11, wherein the carrier gas includes argon.
- [c13] The method of claim 9, wherein the protective layer in-

cludes a nitrogen content greater than a tantalum content.

- [c14] The method of claim 9, wherein the protective layer forming step includes exposing the low-k material substrate for greater than 1000 Langmuirs.
- [c15] The method of claim 9, wherein the substrate is selected from the group consisting of: silicon dioxide (SiO_2), hydro-fluoric (HF) dipped silicon (Si) and a low-k material.
- [c16] The method of claim 9, wherein the first number of cycles is less than the second number of cycles.
- [c17] A tantalum-nitride diffusion barrier region for use with a low-k material, the region comprising:
a protective layer adjacent the low-k material, the protective layer including a tantalum-nitride material having a nitrogen content greater than a tantalum content; and
a substantially stoichiometric tantalum-nitride diffusion barrier layer adjacent the protective layer.
- [c18] The barrier layer of claim 17, wherein there is substantially no diffusion of the low-k material and the protective layer.
- [c19] The barrier layer of claim 17, wherein the tantalum-nitride material is selected from the group consisting of:

Ta_3N_5 , Ta_4N_5 and Ta_5N_6 .

[c20] The barrier layer of claim 17, wherein the protective layer has a thermal stability of greater than approximately 820°C.